

Root Zone Respiration on Hydroponically Grown Wheat Plant Systems

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Abstract

Root respiration is a biological phenomenon that controls plant growth and physiological development during a plant's lifespan. This process is dependent on the availability of oxygen in the system where the plant is located. In hydroponic systems, where plants are submerged in a solution containing vital nutrients but no type of soil, the availability of oxygen arises from the dissolved oxygen concentration in the solution. This oxygen concentration is dependent on the gas-liquid interface formed on the upper surface of the liquid, as given by Henry's Law, depending on pressure and temperature conditions. Respiration rates of the plants rise as biomass and root zone increase with age. The respiration rate of Apogee wheat plants (*Triticum aestivum*) was measured as a function of light intensity (catalytic for photosynthesis) and CO₂ concentration to determine their effect on respiration rates. To determine their effects on respiration rate and plant growth microbial communities were introduced into the system, by *Innoculum*. Surfactants were introduced, simulating graywater usage in space, as another factor to determine their effect on chemical oxygen demand of microbials and on respiration rates of the plants. It is expected to see small effects from changes in CO₂ concentration or light levels, and to see root respiration decrease in an exponential manner with plant age and microbial activity.

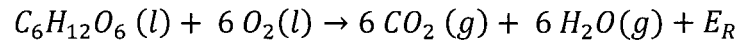
I. Introduction

Advanced Life Support (ALS) applications rely on cost effective and sustainable systems which will reduce a variety of constraints. One challenge is to provide a continuous supply of food access which is readily available. Hydroponic plant systems are ideal for this purpose, since these will permit growing of staple and salad crops with a minimum of resources and planting area. However, the conditions present in space explorations missions differ significantly from atmospheric, sea level conditions; a fact which presents hurdles in the physiological behavior of plants due to the change in their growing habitat. These conditions are established as per engineering and crew requirements to meet physiological body processes and operating conditions for the exploration missions.

Dissolved oxygen concentration (DOC) is a determinant factor in the performance of hydroponic crops, as it determines maximum oxygen delivery to the root zone which will in turn affect plant growth, respiration and plant behavior. DOC concentration is highly dependent on solution temperature, system pressure and oxygen partial pressure in the gas-liquid interface, flow rate near the root zone and biological phenomena attributed to plant growth and microbial growth. Henry's Law permits us to determine these effects and predict HNDS performance in space applications, as DOC levels can be calculated theoretically.

Plant respiration is one of the key processes in terms of understanding plant growth and functioning in a wide range of climates and habitats. During respiration, plants can release up to half of the assimilated carbon fixed during photosynthesis, on a daily basis. This process is dependent on a variety of biological and physiochemical phenomena which affect crop performance. As plants grow older, their respiration rates generally decrease and their root zone biomass increases. Plant respiration is an equilibrium process with photosynthesis, wherein

oxygen and sugars are depleted to produce energy necessary for their biological processes, water and carbon dioxide via the reaction:



During plant respiration, dissolved oxygen concentration decreases with time if no aeration process is implemented. Respiration is dependent on the system the plant is present, and respiration rates change depending on said conditions. This experiment quantifies these rates, as a response to their surroundings.

II. Methodology

The idea behind the project relied on analyzing and obtaining respiration rates for Apogee wheat plants as a function of CO₂ concentration and light level, in a standard system, a system attacked by microbial communities (such as in recycled water in space) and a system with microbial communities, with a soap or surfactant acting on it (simulating gray water). A two-factor factorial, with a minimum of 2 replicates per data set, was obtained, where each replicate was at least two days apart. CO₂ concentrations used were 400 ppm (such as in ambient air) and 1000 ppm (high concentration), and light levels used were of 150 PPF and 300 PPF.

The main equipment was a hydroponic nutrient delivery system which consisted of a recirculation system to deliver nutrient solution from a solution reservoir. Aeration in the solution reservoir was done by a waterfall styled pipe which relied on gravity, and sufficient height to obtain a cascade effect on the bottom tank was allowed. The plant holding tray contained two batches of 250 cm² of area Apogee wheat plants, with a total of 8 plants per batch. Respiration rates were obtained by two oxygen probes located in each part of the system, amongst a multitude of temperature sensors and a pH meter. Microbial growth was promoted by inoculation of the solution with biofilms. The surfactant was a 400 ppm Miranol/Steol solution.

III. Results and Analysis

The results obtained allowed us to determine the rate at which root respiration occurs with plant age, CO₂ concentration and light levels as experimental variables. Microbial communities introduced by inoculation of the system affected plant respiration, due to competition for oxygen demand of the systems present (root respiration, microbial respiration). K_{la} values for oxygen mass transfer coefficients were determined in volumetric phases. A diffusion phenomenon related to oxygen gradients between the root zone and the hydroponic nutrient solution was observed, which explained root respiration and oxygen mobility. Stagnation of oxygen layers in non turbid water layers were analyzed and quantified separately.

Surfactant degradation due to microbial communities was analyzed by chemical oxygen demand testing. Testing agrees with expected theoretical backgrounds, as oxygen demand will increase rapidly due to microbial propagation initially and then slowly decay in time.

IV. Impact of the MUST Internship on my Career Goals

During summer, I gained academic and professional skills, and developed techniques and thinking processes utilized in graduate and formal research. My project allowed me to develop an important skill – the ability to learn of new topics of which one might have no prior or formal training, during a small span of time. The guidance, and constant challenging, of my NASA MUST mentor set high expectations not only for him, but for me as well, which I had every intention of fulfilling and exceeding. He allowed me to grow much, in many manners he might not know.

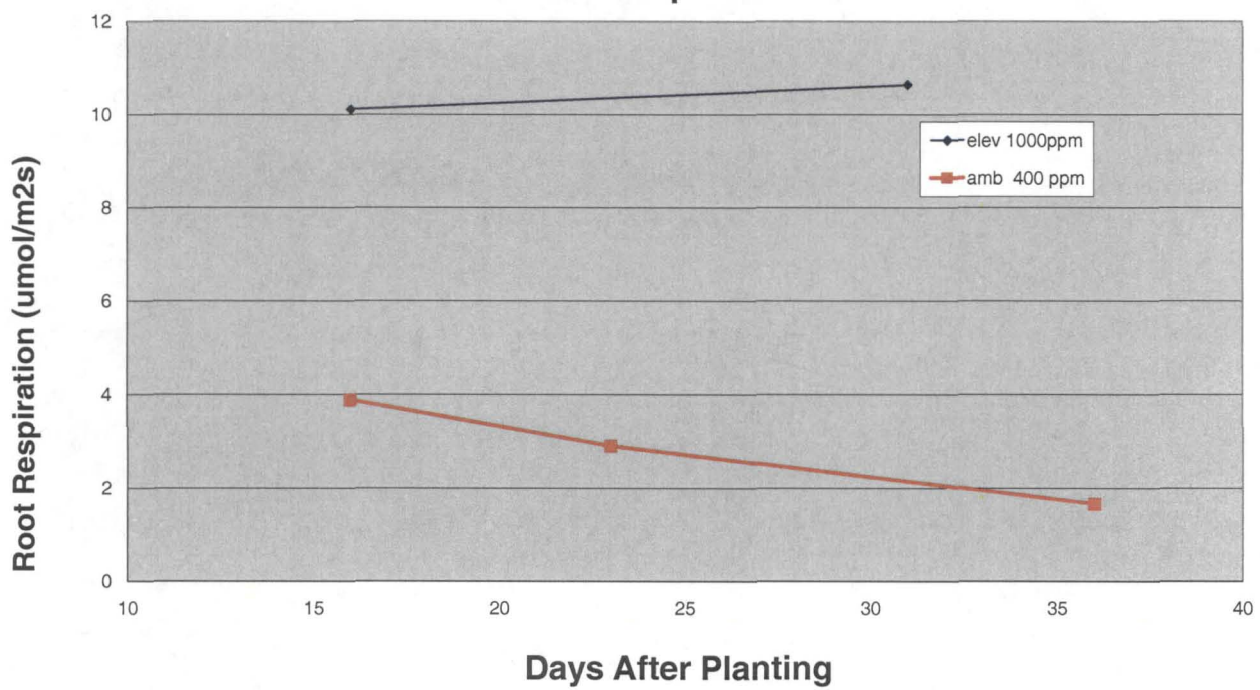
Contrary to Ohio and Glenn Research Center, where my experiences forced me to grow up and mature with my friends in just 10 weeks, I came to Kennedy Space Center ready to participate, and lead, a summer project of my own. Oscar A. Monje, my assigned mentor, was

more than up to the task. Even though he always accompanied me and gave me his advice and personal experiences, he allowed me to be hands-on, take the situation in my own grasp, and think as an engineer and scientist how to best solve the problems encountered. This was put to the ultimate test when, for two and a half weeks, I had to work, analyze and overcome hurdles with minimal assistance from the person who started out being my complete guide.

I started in the NASA MUST program as a shy and insecure 17 year old teenager; and now I am a changed 20 year old secure and confident man with academic, professional and life experiences. The NASA MUST Program and NASA in general has been a defining element in this process. Back when I started, I remember telling MUST Program Manager Holly Triska in an essay to gain entrance into the program I wanted to become an astronaut. Now I tell her something different. Holly, I do not want to become an astronaut – I will become an astronaut. And not because I am good at STEM, or because I have experiences at NASA that give me an edge, but because I have learned something during these past 3 years of my life, and that is to dream big and achieve bigger, and to fight for what one believes until the very end.

This is, most likely, my last written document for the NASA MUST Program. But let it be a testament, and source of inspiration, for the future Rafael Soler's. Here ends the adventure that 3 years ago seemed like a dream. And now that it is over, I am so glad I undertook it, and loved every minute of it, because it allowed me to become who I am today. I love my field, I love my profession, I love my dreams and I just know I'll love who I will become soon. Next summer I'll seek to visit what will become my PhD level graduate school, and move on from that stepping stone. For some, my journey is done. To others, this is enough to close this chapter of their lives. But for me, and thanks to the MUST Program, it's not enough. For me, the journey is just beginning.

Root Respiration vs Time



Root Respiration - CO₂ Response Curve

